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# Feasibility Study for Constructing and Operating a Facility to Manufacture Fuel Pellets from Cotton By-Products

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**Abstract.** *The objective of this study was to explore the cost feasibility of creating a fuel pellet manufacturing operation utilizing cotton gin by-products from a commercial gin processing 55,000 bales of cotton per year. An economic model was developed and evaluated in order to conservatively address the effects of key elements such as marketing, transportation, and manufacturing. The cost system model was developed and analyzed to examine the factors influencing the sensitivity of critical areas such as cost and profits. The cost system model simulated changes for twenty-three cost variables associated with the proposed fuel pellet operation. Results from the analysis indicate the probability of obtaining a 15% return on investment as 34.4% or 59.1% depending on whether the product was shipped to various distribution hubs via truck or rail, respectively. Based upon the information contained in this study, it appears that a fuel pellet operation can be a viable means of utilizing cotton gin byproducts to enhance revenue.*

**Keywords.** Fuel-Pellet, COBY, Gin Waste, Pellet Stove, Gin Trash, Economic Analysis, Energy

## Introduction

Waste or byproducts from cotton ginning facilities have traditionally been considered a financial liability. The accumulation of byproducts behind a gin, during the ginning season, can be rather substantial. It was estimated that in the US, there are over 2.04 million tonnes (2.25 million tons) of cotton byproducts generated each year across the cotton belt (Holt et al., 2000a). In 2001, Texas produced 4,153,866 bales of upland cotton (USDA, 2002). From the bales produced, there was an estimated 750,000 tons of waste produced in the ginning process. A single West Texas gin processing 50,000 bales of cotton would have produced approximately 10,210 t (11,250 tons) of waste byproducts. Past research has explored other ways to utilize gin by-products such as livestock feed, gardening compost, and raw materials for building products. In spite of these efforts, most of the waste generated by the gins is discarded back onto the fields, at a cost to the gin, where it becomes a soil additive (Holt et al., 2000a).

In an attempt to convert cotton by-products into usable materials, the USDA developed a patented system known as the COBY (Cotton Byproducts) process (Holt and Laird, 2001). In the COBY process, byproducts from the ginning operation are treated with gelatinized starch and other additives, and then they are further processed with heat, pressure, grinding, and/or blending. Processing biomass waste streams into fuel pellets could provide a renewable source of energy that could potentially be a viable source of revenue for cotton gins and other industries producing vast amounts of waste biomass.

Commercially available fuel pellets are made up of biomass materials from a variety of commonly grown plants and trees. Waste materials from trees like sawdust and ground wood chips are some of the components of the most common residential fuel pellets. Fuel pellets can be used in pellet burning fireplaces or furnaces for residential or industrial use. Pellet stoves have become more popular in recent years. The Pellet Fuels Institute's (PFI) data shows sales of fuel pellets, in the 2000/2001 heating season increased 14.7% as compared to the previous season, (PFI, 2001). During the 2000/2001 winter months (heating season), 662,200 t (730,000 tons) of fuel pellets were consumed (PFI, 2001). The regional distribution and sales in the U.S for the past six years is shown on Table 1. These data indicate that nationally there has been a steady demand for fuel pellets over the past six years. Some of the primary reasons for the steady sales of fuels pellets are due to a concern for the environment, unseasonably cold winters, and high natural gas and heating oil prices. Table 2 shows a cost comparison between several fuel sources. As can be seen from the table, premium wood pellets are less costly to consume than some of the more common residential fuels such as electricity, propane, and natural gas.

## Objective

The overall objective of this study was to explore the economic feasibility of creating a fuel pellet manufacturing operation utilizing cotton gin by-products from marketing, transportation, and manufacturing aspects. To accomplish the objective, a commercial West Texas gin producing, on average, 55,000 bales of cotton per year was used as a prototype. The cooperating gin provided actual production data needed to determine operational and manufacturing costs that could be associated with a fuel pellet manufacturing facility adjacent to a commercial facility producing cotton byproducts.

## Methods and Materials

To accomplish the overall objective, various goals were set for each of the financial aspects of marketing, transportation, and manufacturing. From a marketing perspective, two goals were set: 1) determine the most economically feasible distribution area or target market region appropriate for the manufacturing location selected, and 2) establish inventory requirements for both raw material and finished product to meet sales requirements. The transportation goals were: 1) to determine the most economical mode of transportation for the finished product, and 2) evaluate the sensitivity of return on investment to freight cost and mode of transportation. The manufacturing goals were: 1) to develop a comprehensive cost system that could be used to determine machine and labor requirements, and 2) to examine economic sensitivity issues such as: sensitivity to raw material availability, capital equipment cost, productivity, transportation cost, labor cost, selling price, etc.

In order to address the three major components of the study (marketing, transportation, and manufacturing) several assumptions were made. The assumptions and their corresponding rationale are listed in Table 3.

The economic model addressed several key elements. Among these are: (1) Annual Operating Profit, (2) Annual Sales, (3) Production per Season, (4) Usable Tonnes of Waste, (5) Total Annual Operating Expense, (6) Capital Depreciation Amount, (7) Total Utility Cost, (8) Total Packing Cost, (9) Total Shipping Cost, (10) Total Freight Cost, (11) Total Rental (Lease) Cost, (12) Total Repair and Maintenance Cost, (13) Total Cost Savings to Gin for Waste Disposal, and (14) Return on Investment (ROI).

To determine the projected values for these key elements, several "what if" analyses were performed using the Crystal Ball™ software package (Crystal Ball 2000, Decisioneering Inc., Denver, CO.). The results are displayed as a forecast of what can be expected based on the laws of probability within a representative distribution.

### *Raw Material, Machinery, and Facility Layout*

A gin located in the West Texas region provided actual production data for the study. During the 2001 crop year, the gin production was 55,000 bales of cotton with an average processing rate of 50 bales per hour. According to the gin, half of their producers use field cleaners during harvesting. Past research has shown that non-field-cleaned cotton will yield about 317.5 to 362.9 kg (700 to 800 lbs) of waste per bale and field cleaned cotton about 136.1 to 158.8 kg (300 to 350 lbs) per bale (Baker et al., 1994; Holt et al., 2000b). Based on these numbers and input from the gin, it was calculated that the gin produced approximately 13,100 t (14,437 tons) of waste during the 2001 ginning season; this averages out to approximately 238.1 kg (525 lbs) of waste per gin bale. Not all waste is recoverable or usable. Other impurities, such as dirt and sand that are not desirable for this type of product also exist in the raw material. From previous research, it was estimated that only about 80% of the total waste generated by the ginning process would be usable for the pellet operation (Holt et al., 2000a). This equates to 190.5 kg (420 lbs) of usable waste per bale. Currently, the gin pays $2.00 per bale to dispose of the waste, which calculates to a yearly disposal cost of $110,000. Table 4 contains the base information for the raw material utilized in this study.

The production facilities size and configuration were determined based on the production capacity of the machinery selected. Since the cooperating gin had ample acreage surrounding the gin, the building housing the fuel pellet processing equipment was to be located adjacent to the current gin operation. This would allow the gin's current waste disposal system to be utilized to feed the fuel pellet operation. The actual construction consists of a 306.6 $m^2$ (3300 $ft^2$) metal building on a concrete slab. The design of the building will utilize natural ventilation and a sufficient amount of lighting to assure a safe work environment. The building will be equipped with a covered loading dock to allow product to be loaded during inclement weather. There will be a 46.5 $m^2$ (500 $ft^2$) allotment of storage area designed into the building that will allow approximately three truckloads of palletized fuel pellet bags to be staged for truck loading. This will limit the on-site storage to approximately eight hours of production.

The machinery selected for this operation was based on the information supplied by various equipment manufacturers and suppliers. The facilities daily production rate was set to handle 100% of the anticipated average waste production of the gin (9525 kg/hr). From a production standpoint, the pellet facility would begin production a one day after the gin began operating. The one day lag would allow a small surplus of material to be accumulated in an effort to minimize the impact that upset conditions, in the gin, would have on the throughput of the fuel pellet operation.

Three Landers model 200-144 pellet mills (Landers Machine Co., Fort Worth, TX) were selected to give versatility to the production capacity. Landers estimates the average throughput, for this type of material, of each pellet mill will be approximately 3.17 t (3.5 tons) with a maximum of 4.5 t (5 tons) per hour. The remaining equipment was sized to handle the capacity of the pellet mills at approximately 75%

of their rated capacity. This type of design allows production to be increased with minimal expenditures for additional equipment (i.e. another pellet mill could be added without having to replace the other equipment). The use of multiple pellet mills also allows the operation to scale back in times of low gin trash production and scale up when the waste production increases. Using this type of system design, a standard rate of 9525 kg (21,000 lbs) per hour could be maintained. During low gin waste generation times, an external feed hopper would be used to supplement the pellet operation by feeding previously bypassed waste (the one day supply) back into the system.

Due to the nature of the cotton by-products, a binding agent is beneficial in holding the pellets together after formation. In prior work, a gelatinized polysaccharide was utilized as the binder, requiring heated mixing tanks (Holt et al., 2001). For this project, a different approach of using a cold starch slurry was implemented. The use of a cold starch slurry eliminated the need for boilers and hot mixing tanks. Our system utilized commercially available polypropylene 11,356 L (3000 gal) holding and mixing tanks. The volume of dry starch used in the process per season, approximately 419,119 kg (924,000 lbs), requires the use of a starch silo to hold bulk product. The cost for a used silo with all the equipment needed to deliver the product to the mixing tanks is approximately $100,000.

Short-term finished product storage was addressed by a staging area built into the pellet operation building and a 371.6 $m^2$ (4000 $ft^2$) short-term storage warehouse. Since the product is sensitive to external conditions it was felt that a short-term on site storage facility would be prudent. The on site warehouse was used to temporarily store approximately 400 pallets or about 362,900 kg (800,000 lbs) of finished product. This equates to 20,000 bags of product that can temporarily be stored until time of shipping.

An automated bagging station was recommended to handle the volume of bags produced. The automated bagging station would fill each bag with 18.14 kg (40 lbs) of pellets, heat seal the bags, stack 50 bags on a pallet, and then wrap the pallet with cellophane. This setup represented 17.2 % of the total capital cost of the project. Several laborers, if deemed necessary, could possibly replace the bagging system. At standard production there will be 525 bags produced per hour, which will be used to create 10.5 pallets.

A building of 306.6 $m^2$ (3300 $ft^2$) was determined to be sufficient to house the production equipment. An estimate of $\$115.72/m^2$ ($\$10.75/ft^2$) was obtained from a contractor that currently constructs these types of buildings. The machine installation and electrical costs were obtained from estimates of similar facilities, equipment manufacturers, and cost engineering text. Cost engineering data were obtained from Humphreys and Wellman (1996). To cover startup and miscellaneous cost (including new employees training and minor unforeseen expenses), a value of 10% of the total machinery cost was used.

### *Labor Cost*

Labor for this operation used a combination of full-time temporary contract labor and full time permanent positions. The ginning industry has traditionally used full-time temporary employees to work during the ginning season only. After completion of the ginning season, these employees are released.

Direct labor included laborers, forklift operators, front-end loader operators, and lead men for each shift. As mentioned before these employees are full-time temporary contract labor for the duration of the production season. For this reason the employees will work straight time with no benefits. Hourly pay rates are higher than the minimum wage usually paid in the area and reflect the need for employees that are willing to work the time required.

The pellet operation will have two full-time employees: a manager and foreman. There will also be one six-month clerical position. It is important to have these as annual positions so that a level of operational expertise is maintained. The full-time employees will be responsible for training the employees each year as well as working to develop sales and marketing for the company. This type of arrangement will work to maintain the stability of the operation during the off-season. For this study, a twenty-two hour workday was used with two hours of cleanup and minor maintenance. Three eight-hour shifts were used with seven employees per shift not including the Manager, Foreman, and Secretary.

Each shift was comprised of three Laborers, one Leadman, one Loader Operator, and two Floor Operators.

### *Expenses*

Operational expenses comprise approximately 62% of the total cost of the product and are directly related to the run time of the production facility. In this case the dryer fuel (natural gas) and electricity are consumed for approximately three months out of the year. The remaining nine months of the year the utility consumption is negligible.

The bags used for this process are unique. They are doubled walled and perforated. The perforation allows the product to breath and prevents moisture build-up during and after the bagging process. They are also designed to offer the consumer a tear resistant package.

As for the mobile material handling equipment used, lease of a front-end loader and forklift was a more viable option than purchasing since purchasing would add more capital cost to the project. The other expense related to the mobile material handling equipment, is that of fuel.

Repair and maintenance costs were obtained from estimates from equipment manufacturers based on their experience of having this type of equipment in the field. This estimate is based on tonnes of production and works out to be $2.76 per tonne processed ($2.50 per ton). An overall reduction in gin operating expense of $110,000 was taken as an annual cost savings. This reduction was the result of cost savings realized due to the gin not having to dispose of waste at a cost of $2.00 per bale ginned.

The product used, in this analysis, for binding the pellet together was feed grade cornstarch. A solution of cornstarch mixed in water will be added at a rate of 4% by weight of waste being fed into the pellet mills. Based on 18.14 kg (40 lbs) per bag of fuel pellets there would be 0.725 kg (1.6 lbs) of cornstarch per bag of fuel pellets produced. With a season's production of 577, 500 bags, there would be 419,119 kg (924,000 lbs) of cornstarch consumed. The actual cost per bag would be $0.10 for the cornstarch binder.

Since the COBY process is a patented process, the licensee is entitled to royalties. The royalties for making a fuel pellet are set at 4% of the profit per 0.91 t (1 ton) of the product produced. The royalties were considered in the operational cost of the plant.

### *Transportation*

In an effort to establish transportation cost parameters, four shipping points were selected. The four shipping distribution hubs (Albuquerque, NM.; Denver, CO.; and Kansas City, MO.; Lubbock, TX.) were used to service the five destination states (NM, CO, MO, KS, and TX). In both trucking and rail estimates, the cost of shipping was directly related to the distance traveled. The initial cost system was set up with the general assumption that the fuel pellets would be shipped in equal proportions to the three distribution hubs. Table 5 contains freight cost per bag for equal destination allocation and several different destination combinations. The shipping cost is expressed as a weighted average and summed to obtain the freight cost as an average cost per bag. The second part of the table demonstrates the shipping allocation by destination effect on cost and profit per bag. It should be noted that shipping the finished product to the nearest rail spur (64.4 km (40 mi)) had an associated transportation cost of $0.114 per bag.

### *Model Development and Analysis*

To evaluate the economic feasibility of building and operating a cotton byproduct processing plant, a spreadsheet model was developed and used to perform forecast potential costs and revenues associated with such a facility.

Since changes in costs of materials, labor, supplies, transportation, and other variables occur and can have a significant affect on the feasibility of a project, twenty-three variables were assigned distributions with ranges deemed appropriate based on research and experience. Table 6 presents a list of all the variables and their respective distributions and parameters used in the forecast model for all the different analyses performed.

Since cost overruns can occur during construction, one of the primary variables used in the model was capital cost. During the simulations, the capital cost was allowed to increase up to 15% above the baseline of $1,573,473. The 15% increase was derived at by taking the percent variation of the price ranges encountered when obtaining equipment cost and multiplying it by two.

## Results and Discussion

The forecasting model performed 50,000 iterations adjusting each variable within the specified range for the assigned distribution. The model output contained the mean and standard deviation of key elements such as number of years to payback, ROI, annual profit, cost per bag, etc. based on cost variable changes within the specified distributions. The break even selling price per bag was established based on market information gathered from the Pellet Fuels Institute and other similar organizations. When manufacturing and transportation costs were taken into consideration, the average break-even selling price for fuel pellets being trucked and shipped by rail was $1.99 and $1.78, respectively. The break-even price per bag standard deviation for the truck and rail were $0.17 and 0.15, respectively.

An analysis was performed to examine the break-even waste quantity at a delivered selling price of $2.33 per 18.14 Kg (40 lb) bag. In the analysis, it can be seen that as waste quantity is reduced the operation's ability to cover cost is inhibited. The actual break even waste quantity varied depending on the mode of transportation used. The breakeven quantities for truck and rail where 6319 t (6966 tons) and 5113 t (5636 tons), respectively. These breakeven values would equate to 33,175 and 26,839 bales of cotton, for truck and rail, respectively, with an average waste per bale of 190.5 Kg (420 lbs). The break-even bale quantity is significant since the worst crop year this gin has experienced in the last 25 years was 21,000 bales, which equates to 4001 t (4410 tons) of waste. For years where the cotton gin processed fewer bales than the breakeven quantity, additional waste would need to be purchased in order to return a profit.

### *Transportation Sensitivity*

Since transportation costs are key to the total cost of the product, an analysis was performed to determine if the cost of the product would be sensitive to a change in freight charges. The analysis used incremental values from a 25% decrease to a 50% increase in freight cost. An increase in trucking freight cost is more significant because of the limited capacity of each truckload, 1100 bags. Whereas a change in rail freight cost is distributed over the carloads carrying capacity of 5000 bags. This would indicate a need to shift the shipping allocation more heavily toward rail.

Tables 7 and 8 show the top six variables that have the largest impact on the sensitivity of ROI and Production Cost per Bag for both truck and rail, respectively. In Table 7, the top two variables are the same for both modes of transportation with selling price per bag being the primary contributor to the variance of ROI. The primary difference between truck and rail is the inclusion of freight cost. Truck freight cost added to the variation of ROI by 8% whereas rail freight only affected the variation by 0.7%. Table 8 indicates that the number of bales ginned was the primary contributor to variance associated with the Production Cost per Bag. Similar to Table 7, Table 8 reveals freight cost to be the major difference between the variations for truck and rail. Truck freight cost contributed to the variation in Production Cost per Bag by 27% whereas rail freight cost affected the variation by only 3.3%.

### *Cost System*

By approaching this project as an enhancement to a current operation, a Minimum Attractive Rate of Return (MARR) was not predetermined. However, based upon the target value given to us by the participating gin the minimum Return on Investment (ROI) desired was established at 15%. The cost system model was developed in Microsoft Excel spreadsheets and was used to examine factors that influenced the sensitivity of critical areas such as cost and profits. One such area was the relationship between finished product transportation and the amount of waste available for the pellet operation. Rates of return were calculated using the future value of the capital cost if the money was simply invested for 10 years. These values were used as benchmarks. The waste generated, in the form of thousands of bales ginned, was manipulated until the profits matched the benchmark values. This allowed a comparison to be made that showed how many bales would have to be processed in order to meet the various return rates.

With 15% return on investment, as a minimum standard, transporting finished product by truck did not appear to be a viable option. For trucking to be viable the long-term interest rate on capital cost had to be 5% or below. Using rail as the primary transportation is less sensitive to a change in interest rate and was found to meet the required ROI even at interest rate levels as high as 17%. Figure 1 shows the ROI changes to variations in the interest rates.

### *What-If Analysis*

Several "what if" analysis were produced using the Crystal Ball™ software package. The first analyses examined a Return on Investment (ROI) of 15% as it relates to the current cost system. A total of 50,000 trial runs were performed. The results were displayed as a forecast of what ROI can be expected based on the laws of probability within a normal distribution. The results of this analysis for both modes of transportation are contained in Table 9. The mean ROI for truck and rail were 11.07% and 17.36%, respectively. The certainties of obtaining a 15% ROI, based on the assumptions of the model, for truck and rail were 34.36% and 59.13%, respectively.

The same process was used to forecast the effect that total usable waste has on the process. Using the same basic arrangement, the total tons of usable waste per season was examined using 50,000 trial runs. The results of this forecast are contained in Table 10.

This forecast supports the premise that the operation will be viable even in years with low waste quantities from a cost per bag perspective. At the 10% value of 7512 t (8281 tons), the production cost per bag would be $2.19 for truck transportation and $1.97 for rail. Based on this cost and a delivered selling price of $2.33 per bag the ROI for this combination would be 3.77% and 9.55% respectively. The forecast results in Table 10 suggest that 90% of the time the ginned bales should exceed 7512 t (8281 tons) which would allow a modest ROI in seasons of poor supply. To obtain the ROI of 15%, the minimum quantity necessary would be 11,073 t (12,206 tons) if shipping by truck and 8882 t (9791 tons) if by rail.

Based on the model, the average number of years to payback the capital cost would be 7.62 for truck and 4.68 for rail. These averages are based on the capital cost being allowed to vary uniformly from 1.57 to 1.81 million dollars. The interest rate on the capital cost investment varied according to a normal distribution with a mean of 8% and a standard deviation of 1%.

## Conclusions

Using the information contained in this study it does appear that a fuel pellet operation can be a profitable development. Treasury Bills return about 3.61% on a 10-year investment (as of May 13, 2003; Bloomberg.Com, 2003). The stock market historically returns approximately 12% (Coe, 2002; Stuhlreyer, 2002; and Wibel, 2002). Based upon the assumptions and values used in the forecast model, the ROI of 15% would have a 34.36% and 59.13% chance of certainty if transporting the product to market by truck or rail, respectively. To be able to achieve the optimal transportation cost a combination of truck and rail will most likely be used.

The ROI can be further improved by examining the projects capital costs and narrowing the estimates to quotable amounts. The information for this project was gathered in good faith. Pricing figures contained in this study are for budgetary estimation only and are not intended as quotable amounts.

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Table 1. Tonnes of fuel pellets distributed in the United States by region (PFI, 2001).

| Region | 2000-2001 | 1999-2000 | 1998-1999 | 1997-1998 | 1996-1997 | 1995-1996 |
|---|---|---|---|---|---|---|
| U.S. Pacific | 185,100 | 213,600 | 209,600 | 214,100 | 206,800 | 237,700 |
| Mountain | 109,800 | 80,740 | 108,900 | 97,980 | 97,980 | 111,600 |
| Central | 39,010 | 15,880 | 28,120 | 44,450 | 32,660 | 17,240 |
| Great Lakes | 23,590 | 17,330 | 24,490 | 19,960 | 40,820 | 32,660 |
| Northeast | 178,700 | 133,400 | 122,500 | 139,700 | 129,700 | 97,070 |
| Southeast | 57,150 | 56,250 | 52,620 | 44,450 | 44,450 | 35,380 |
| Total | 593,350 | 517,200 | 546,230 | 560,640 | 552,410 | 531,650 |

Table 2. Fuel cost comparison of wood pellets to other commonly used fuels (PFI, 2001).

| Fuel | Price ($) | Cost ($) per kJ (MMBTU) of usable heat |
|---|---|---|
| Premium Wood Pellets – 6% moisture, 19.07 MJ/kg (8200 BTUs/lb) 80% efficiency | 176.36 per tonne (160 per ton) | 11.56 (12.20) |
| Electricity – 3603 kJ/kW-h (3415 BTUs/kW-h), 95% efficiency | 0.10 per kW-h | 29.19 (30.80) |
| Propane – 359.4 MJ/L (90,000 BTUs/gal) 80% efficiency | 0.37 per liter (1.40 per gallon) | 29.19 (30.80) |
| Oil #2 – 551 MJ/L (138,000 BTUs/gal) 80% efficiency | 0.317 per liter (1.20 per gallon) | 10.29 (10.86) |
| Natural Gas – 3599.4 kJ/kW-h (100,000 BTUs/therm) 80% efficiency | 0.028 per MCM (1.00 per MCF) | 11.85 (12.50) |
| Coal – 27.9 MJ/kg (12,000 BTUs/lb) 75% efficiency | 176.36 per tonne (160 per ton) | 8.42 (8.88) |
| Firewood – 18.96 kJ (20 MMBTU) 65% efficiency | 130 per cord | 9.48 (10.00) |

Note: Efficiency Rating is based on newer modern appliances. Older heating appliances may be far less efficient therefore increasing cost per kJ.

Table 3. Assumptions with their corresponding rationale used in the economic analysis.

| Assumptions | Rationale |
|---|---|
| 1. There is a current demand for the product. | From PFI, 2001 (See Table 1). |
| 2. All pellets produced will be bagged [18.14 kg per bag (40 lbs)]. | Standard practice for the industry (PFI, 2001). |
| 3. All pellets will be for the consumer market. | No commercial sales of pellets in bulk (worst-case scenario). |
| 4. Distribution will be limited to a five state area (Texas, New Mexico, Colorado, Missouri, and Kansas). | History of fuel pellet consumption and proximity to the manufacturing plant. |
| 5. All production will be sold wholesale to existing distribution companies. | Marketing strategy |
| 6. There will be no long term warehousing of finished product. | Manufacturing strategy |
| 7. A strategic advantage will be gained by operating in the five state region selected. | Based on current regional consumption (PFI, 2001) and proximity to the manufacturing plant. |
| 8. No account for product spillage or loss | Spillage will be re-worked. |
| 9. All costs include shipping the product to one of three distribution hubs. | Marketing strategy |
| 10. No taxes or insurance costs will be considered in the analysis. | Analysis decision since taxes and insurance can vary based on plant location. |
| 11. All transportation will be accomplished by rail or truck. | These are considered the two extremes for transportation. |

Table 4. Cooperating gins production information used to determine gin waste production.

| Description | Value |
|---|---|
| Annual Production (Bales) | 55,000 |
| Bales per hour | 50 |
| Average waste / bale (kg) | 238 |
| Tonnes of waste / season | 13,097 |
| Usable waste % | 80% |
| Tonnes of usable waste / season | 10,478 |
| Gin days of operation | 50 |
| Hours of operation per day | 22 |
| Tonnes of usable waste / h | 9.53 |

Table 5. Freight cost ($) per bag for Albuquerque, NM; Denver, CO; Kansas City, MO; and Lubbock,TX.

| Freight Cost per Bag | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Distribution | Truck Allocation (%) | Truck ($) | Truck Wt. Avg. ($) | Rail Allocation (%) | Rail ($) | Rail Wt. Avg. ($) |
| Alb | 1/3 | 33.3 | 0.561 | 0.187 | 33.3 | 0.329 | 0.110 |
| Den | 1/3 | 33.3 | 0.750 | 0.250 | 33.3 | 0.391 | 0.130 |
| KC | 1/3 | 33.3 | 0.953 | 0.317 | 33.3 | 0.453 | 0.151 |
| Cumulative Cost/Bag | | | | 0.754 | | | 0.391 |
| Location | | Allocation | Truck Total Cost ($) | Truck Profit ($) | | Rail Total Cost ($) | Rail Profit ($) |
| 1/3,1/3,1/3 | | A | 2.101 | 0.399 | A | 1.860 | 0.640 |
| 1/4,1/2,1/4, | | B | 2.100 | 0.400 | B | 1.860 | 0.640 |
| 1/4,1/4,1/2 | | C | 2.150 | 0.349 | C | 1.870 | 0.630 |
| 1/2,1/4,1/4 | | D | 2.050 | 0.447 | D | 1.840 | 0.660 |
| 3/4,1/8,1/8 | | E | 1.980 | 0.519 | E | 1.820 | 0.680 |
| 1/8,3/4,1/8 | | F | 2.099 | 0.401 | F | 1.860 | 0.640 |
| 1/8,1/8,3/4 | | G | 2.226 | 0.274 | G | 1.900 | 0.600 |
| 100% Alb | | H | 1.908 | 0.592 | H | 1.800 | 0.700 |
| 100% Den | | I | 2.097 | 0.403 | I | 1.860 | 0.640 |
| 100% KC | | J | 2.300 | 0.200 | J | 1.920 | 0.580 |
| Cost/bag for Lubbock | | 0.114 | | | | | |

Table 6. Distributions and their associated parameter variables used in the forecast modeling.

| Variable | Distribution | Units | Distribution Parameters | Range |
|---|---|---|---|---|
| Pellet mill production rate | Normal | kg/hr (lbs/hr) | Mean = 3402 (7500) Std. Dev. = 703 (1550) | 2268 - 4536 (5000 – 10,000) |
| Waste per bale | Normal | kg/hr (lbs/hr) | Mean = 238 (525) Std. Dev. = 23.8 (52.5) | 166.7 – 309.6 (367.5 – 682.5) |
| Usable waste | Normal | % | Mean = 80 Std. Dev. = 4 | 68 - 90 |
| Number of bales ginned | Normal | # | Mean = 55,000 Std. Dev. = 10,000 | 25,000 – 66,000 |
| Starch applied | Normal | % | Mean = 4.0; Std. Dev. = 0.4 | 2.8 – 5.2 |
| Price per kWh | Normal | $ | Mean = 0.055; Std. Dev. = 0.003 | 0.051 – 0.065 |
| Cost of starch | Triangular | $/Mg ($/ton) | Min. = 99 (90); Max. = 149 (135); Likeliest = 127 (115) | 99 – 149 (90 – 135) |
| Bag cost | Normal | $ | Mean = 0.25; Std. Dev. = 0.015 | 0.205 – 0.295 |
| Pallet cost | Triangular | $ | Min. = 6; Max. = 11; Likeliest = 8 | 6 – 11 |
| Maintenance and repair cost | Normal | $/Mg ($/ton) | Mean = 2.50 Std. Dev. = 0.25 | 1.75 – 3.25 |
| Natural gas cost | Triangular | $/Mcm ($/Mcf) | Min. = 0.119 (3.37); Max. = 0.145 (4.11); Likeliest = 0.132 (3.74) | 0.119 – 0.145 (3.37 – 3.74) |
| Gasoline cost | Normal | $ | Mean = 1000; Std. Dev. = 50 | 850 – 1150 |
| Selling price per bag | Normal | $ | Mean = 2.33 Std. Dev. = 0.23 | 1.90 – 2.75 |
| Interest rate | Normal | % | Mean = 8.0; Std. Dev. = 1.0 | 5.0 – 11.0 |
| Office operational cost | Triangular | $ | Min. = 850; Max. = 1150; Likeliest = 1000 | 850 – 1150 |
| Disposal cost | Normal | $ | Mean = 2.00; Std. Dev. = 0.67 | 0.01 – 4.00 |
| Percent of product shipped to distribution hub “X” | Uniform | % | Min. = 0.0% Max. = 100% | 0.0 – 100 |
| Laborer wages | Pareto | $/hr | Location = 5.25; Shape = 2 | 5.25 – 6.50 |
| Leadman wages | Pareto | $/hr | Location = 7.25; Shape = 2 | 7.25 – 8.75 |
| Loader operator | Pareto | $/hr | Location = 6.00; Shape = 2 | 6.00 – 7.25 |
| Floor operator | Pareto | $/hr | Location = 5.75; Shape = 2 | 5.75 – 6.75 |
| Secretary | Pareto | $/hr | Location = 6.50; Shape = 2 | 6.50 – 7.50 |
| Capital cost | Uniform | $ | Min. = 1,573,473 Max. = 1,809,493 | 1,573473 – 1,809,493 |

Note: Mg = Megagram = 1 tonne

Table 7. Top six variables, for transportation by truck and rail, that contributes to the variation of return-on-investment (ROI).

| Variable | Contribution to Variance (%) |
|---|---|
| Transportation – Truck | |
| Selling Price per Bag | 46.5 |
| Number of Bales Ginned | 28.1 |
| Freight Cost | 8.0 |
| Amount of Waste per Bale | 6.6 |
| Current Waste Disposal Cost | 4.9 |
| Percent Usable Waste | 1.7 |
| Transportation – Rail | |
| Selling Price per Bag | 41.0 |
| Number of Bales Ginned | 37.1 |
| Amount of Waste per Bale | 9.8 |
| Current Waste Disposal Cost | 4.4 |
| Percent Usable Waste | 2.6 |
| Capital Cost of Facility | 1.9 |

Table 8. Top six variables, for transportation by truck and rail, that contributes to the variation of production cost per bag.

| Variable | Contribution to Variance (%) |
|---|---|
| Transportation – Truck | |
| Number of Bales Ginned | 38.6 |
| Freight Cost | 27.0 |
| Current Waste Disposal Cost | 15.9 |
| Amount of Waste per Bale | 6.5 |
| Pellet Mill Hourly Production | 3.2 |
| Interest Rate | 1.9 |
| Transportation – Rail | |
| Number of Bales Ginned | 50.9 |
| Current Waste Disposal Cost | 20.9 |
| Amount of Waste per Bale | 9.2 |
| Pellet Mill Hourly Production | 4.1 |
| Freight Cost | 3.3 |
| Percent Usable Waste | 2.5 |

Table 9. Distribution of return-on-investment (ROI) for both modes of transportation evaluated.

| Transportation - Truck | |
|---|---|
| Percentile (%) | ROI (%) |
| 0.0 | -15.00 |
| 10.0 | 0.27 |
| 20.0 | 3.64 |
| 30.0 | 6.29 |
| 40.0 | 8.73 |
| 50.0 | 11.07 |
| 60.0 | 13.50 |
| 70.0 | 16.19 |
| 80.0 | 19.44 |
| 90.0 | 24.07 |
| 100.0 | 59.41 |
| Transportation – Rail | |
| Percentile (%) | ROI (%) |
| 0.0 | -10.66 |
| 10.0 | 5.84 |
| 20.0 | 9.42 |
| 30.0 | 12.28 |
| 40.0 | 14.86 |
| 50.0 | 17.36 |
| 60.0 | 19.95 |
| 70.0 | 22.80 |
| 80.0 | 26.15 |
| 90.0 | 30.99 |
| 100.0 | 64.37 |

Table 10. Forecast of the amount of usable waste available.

| Percentile (%) | Usable Waste |
|---|---|
| 0.0 | 3457 tonnes (3811 tons) |
| 10.0 | 7512 tonnes (8281 tons) |
| 20.0 | 8340 tonnes (9193 tons) |
| 50.0 | 9978 tonnes (10,999 tons) |
| 80.0 | 11,619 tonnes (12,808 tons) |
| 90.0 | 12,447 tonnes (13,721 tons) |
| 100.0 | 17,986 tonnes (19,826 tons) |

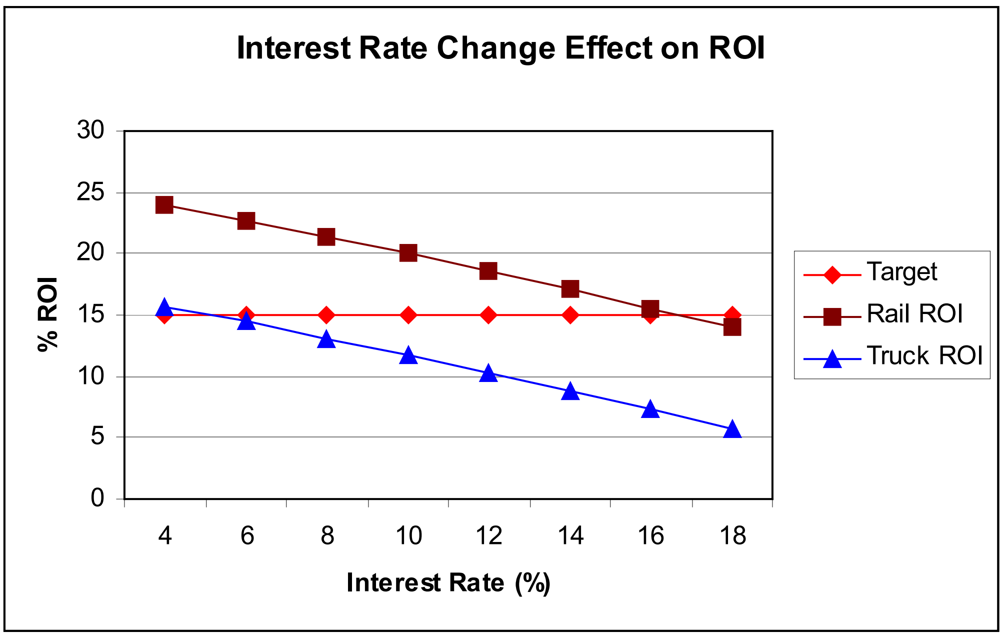


**Figure 1. Effect of changes in interest rate on return on investment (ROI).**